

Appendix F

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APPENDIX F

THERMAL BLANKET REQUIREMENTS

F1. INTRODUCTION AND SUMMARY

The intent of this Appendix is to provide the principle investigators for Shuttle-borne experiments enough information to design and fabricate insulation systems to protect scientific instruments from Shuttle environmental temperature extremes. While special requirements occasionally dictate the localized use of a foam or batt insulation, the great majority of payloads will be insulated with Multi-Layer Insulation (MLI) discussed in this section. Special requirements, however, occasionally dictate localized use of a foam or batt insulation.

A typical MLI contains 10 to 50 layers of a metallized film, with alternating layers of a low-density spacer material. MLI relies on low-contact conduction between layers, low-gas conduction in the vacuum environment, and highly reflective metal surfaces to minimize both conduction and radiation heat transfer. This information is intended primarily for the experimenter with relatively little spacecraft experience who is adapting a near-room-temperature laboratory or sounding rocket-class instrument for flight on the Shuttle.

The information provided has been compiled from existing data sources, including the Shuttle Payload Accommodations Handbook (Reference 1*), a Lockheed study of MLI insulation (Reference 2*), and from Grumman insulation data and fabrication procedures developed over a period of years in support of the Apollo lunar landing vehicle.

F2. REQUIREMENTS FOR HH APPLICATION

F2.1 Temperature Extremes

During pre-launch checkout, launch, and re-entry, the temperature of a payload insulation system is not under the experimenter's control. Since the multilayer insulation is composed of many very light-weight layers of aluminized film and spacer material, its temperature will closely follow the Shuttle bay environment temperature. The highest environment temperature reached in any of these mission phases occurs during re-entry when vents allow air in to minimize the pressure differential across the Shuttle structure. This has been established in Reference 1 as 80oC.

This criteria, along with flammability, has led to the selection of aluminized polyimide (Kapton) as the standard insulation material for Shuttle payloads. Kapton is not flammable, and does not shrink or degrade at temperatures up to approximately 400oC. On-orbit, the insulation outer layer temperature depends upon the properties of the external coating and on the orientation of the surface to the sun and the Earth. Typically, insulation outer layer surface temperatures are expected to fall in the -160oC to 90oC range.

- See subsection F.3 for references

F2.2 Humidity

Aluminized Kapton is irreparably damaged by liquid water. Water dissolves the vapor-deposited aluminum which provides the high-radiation reflectance necessary for an efficient insulation system. Normal humidity levels of 30 to 50 percent existing in the laboratory or in the Shuttle bay during ground checkout will not harm the insulation system. The main consideration of exposure to normal humidity prior to thermal vacuum testing or flight is that it will require sufficient time in a vacuum to desorb the water molecules from the blanket before optimum blanket performance is reached. High humidity may be experienced during landing, so insulation systems should be inspected prior to re-use. In any application where high humidity, or indeed actual condensation on the MLI blanket is anticipated, consideration should be given to the use of gold-coated Kapton rather than the standard aluminized Kapton.

F2.3 Launch And Re-Entry Pressure Transients

Sufficient vent paths must be provided in the insulation system to prevent a pressure differential from tearing individual layers or ballooning the entire assembly away from the payload. The launch profile is the critical pressure transient, since typically, the blanket is only moderately restrained (by tape, velcro, or stand-offs) to resist motion away from the payload. To minimize lost mission time, the MLI venting system must allow rapid inner-layer venting and, hence, a rapid attainment of high effectiveness. An increasing external pressure during re-entry is less significant, since it will usually only result in slight compression of the blanket against the payload structure. Care must be taken in the design of the MLI system however, to allow repressurization of the experiment cavity.

F2.4 Off-Gassing Constraints

Any payload to be flown on the Shuttle must be designed to meet off-gassing criteria. The concern is that a molecular cloud in the vicinity of the Shuttle, plus actual condensation of off-gassed molecules on optical surfaces, can greatly degrade experiments. The primary NASA criteria is to require use of materials that exhibit less than a 1% TML, and .1% collected Volatile Condensable Material (VCM) when heated to 125°C for the NASA standard test described in Reference 3 (see subsection F.3).

F2.5 Grounding

A relatively new criteria imposed on Shuttle payloads is the grounding of the insulation system. Since the multiple alternating layers of spacer and metallized film can act as a large capacitor covering essentially the entire payload, NASA requires layer-to-layer grounding to avoid electrostatic charge buildup.

F2.6 External Coating Reflectance

NASA has established the goal of minimizing reflections off payload surfaces that could hamper the astronaut's visibility, affect crew tasks, or degrade neighboring experiments. Therefore, although specular reflecting surfaces are not forbidden, it is desirable to use diffuse reflecting external surfaces on insulation blankets. Paints and cloth coverings are generally diffuse, but a commonly used external layer is a thicker (2 mil) layer (for handling protection) of aluminized

Kapton (Kapton side out), and this is a primarily specular surface. Another common surface used to obtain a low-solar absorptivity is silver-coated Teflon (Teflon side out), which can be obtained in either specular or diffuse versions. Until a firm criteria is established, the acceptability of specular outer surfaces will probably be determined by each Shuttle vehicle manager, based on the experiments and anticipated crew tasks for that flight.

An important design consideration for external blankets is the so-called "greenhouse" effect. This occurs when the outermost layer is semi-transparent to solar energy (beta cloth, plain Kapton). If the next outermost layer has a lower temperature, then the solar energy absorbed in the layer will result in a high-layer temperature and the energy will be re-radiated equally from both sides of the layer. Therefore, when a semi-transparent outermost-layer is used, the next layer should be one-side aluminized Kapton with the Kapton side out so that the energy absorbed in this layer is primarily re-radiated to the outer layer and then to space.

F2.7 Flammability

This is an extremely important criteria requiring controlled testing of any new materials contemplated for Shuttle use. Fortunately, non-flammable materials are available that are completely acceptable for MLI systems. These are aluminized Kapton for the reflective layer and various dacron and glass nets for the separator.

F2.8 Acceleration, Vibration, And Acoustic Environments

MLI systems are extremely light (.1 lb/ft²). Hence, they are relatively easy to secure to the payload to survive the Shuttle acceleration, vibration, and acoustic environments during launch and re-entry. These design criteria are fully discussed in Reference 1 (see subsection F.3).

F2.9 Weight

The maximum weight of the payload MLI systems is not a Shuttle requirement but must be considered for standoff design and cost. The experimenter should estimate a realistic blanket-performance goal. By making use of the relatively simple design approaches and fabrication techniques discussed in this report, it is possible to obtain the highest effectiveness for a given blanket weight.

F2.10 Other Factors

There are a number of mission unique-factors the experimenter must consider. These include installation time, on-orbit access, post landing access, and re-usability.

F3. REFERENCES

1. Space Shuttle System Payload Accommodation, JSC07700 Volume XIV, Revision F.
2. NASA CR-134477 "Thermal Performance of Multi-layer Insulation", Lockheed Final Report, April 1974.
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6. Holmes, V.L., et. al., "Measurement of Apparent Thermal Conductivity of Multilayer Insulations at Low Compressive Loads", AIAA Paper 72-367, 1972.